



Performance Evaluation of a Cowpea Thresher at Various Moisture Contents

*Eric Amoah Asante, Wilson Kwaku Kallai, John Bonney, Randy Amuaku.

Koforidua Technical University, Koforidua, Ghana, Faculty of Engineering

**eaamoah@yahoo.com*

Abstract

To improve the quality of threshed cowpea (*Vigna unguiculata* L.), produced by rural farmers in Ghana, and determine the best machine-crop parameters combination for optimum performance, a cowpea thresher was developed and evaluated at different moisture contents. The cowpea after harvesting was divided into five units and dried to 20.7, 18.4, 15.5, 13.5 and 12.6 % seed moisture contents. The effect of seed moisture contents on threshing quality was assessed at 735 rpm rotor speed using the white with black eye cowpea. The performance test showed that 12.6 % had the highest throughput of 77.56 kg/h with the lowest of 66.28 kg/h from the 20.7%. The seed damage ranged from 1.64 to 9.46 % and threshing efficiency from 93.11 to 99.40 %. Analyses done at 5% level of significance indicated no significant difference in the throughput and threshing efficiencies. However, seed damage had significant difference. Subsequently, analysis performed on the data for seed loss of 12.6 and 13.5 % which were the best performing moisture contents showed no significant differences. Therefore, seed moisture contents less than 13.5 % and rotor speeds less than 735 rpm are the crop- machine parameters combination for optimum thresher performance.

Key words: Design; Throughput; Impact Force; Seed Loss; Simulation

1. Introduction

Cowpea (*Vigna unguiculata* L. Walp) is an annual legume crop (Yalcin, 2007) and originated from Africa. Nowadays, it is a legume widely adapted and grown throughout the world (Gomez, 2004). The grain contains as high as 24.8 % protein and improves soil properties especially in sandy and light soils (Morad et al. 2007). It has high economic value which makes it the most important legume in Africa (Murdock and Baoua, 2014; Langyintuo et al. 2003) and in many parts of the world (Langyintuo et al. 2003). Once the crop has been harvested, the seeds must be dislodged from the panicle, and the process is called threshing. The difficulty in the threshing process has existed at the early stages when man started using cowpea seeds as food (Irtwange 2009). Meanwhile, it is the most important practice in the grain production chain. Threshing loss, grain damage, and cleaning efficiency are the most qualitative key parameters for evaluating thresher operation performance (Salari et al. 2013). The threshing can be done either mechanically or manually (Adekanye and Olaoye, 2013). Both methods

of threshing cause a lot of breakages to the seeds. Manual threshing is done using pestle and mortar or by spreading the dried crop on the floor where it is beaten with a stick (Maunde, 2011). It is characterized with time wasting, threshing losses, and high drudgery (Olaoye, 2011). To reduce the incidence of stone, a tarpaulin or similar materials are spread before threshing. The seeds are then separated by winnowing (Fulani et al, 2013). Mechanical threshing is the use of either engine or electric motor to drive the machine for the threshing of crops. In axial flow threshers, the crop moves spirally between the threshing drum and concave for several complete turns. The crop is thus threshed by repeated impact of the threshing pegs. The process produces high quality product, eliminates drudgery associated with local threshing system and reduces threshing losses (Manes et al., 2015; Olaoye, 2011).

The efficiency of threshing operation is affected by feeding method, cylinder speed, concave-to-cylinder clearance and moisture content (Kepner et al., 1978). A study on the threshing of cowpea was carried out by Sharma and Devnani (1980), and

reported an increase in the threshing efficiency with the increase of cylinder speed. The results however, reported a decrease in the threshing efficiency with the increase of feed rate and concave clearance. The authors further reported 5 % visible grain damage at higher speeds with low germination percentage. In another study Herbek and Bitzer (2004) reported that cylinder speeds ranging from 400 to 800 rpm were generally sufficient and that greater seed damages are caused by higher cylinder speeds ranging from 700 to 800 rpm. The authors therefore suggested that it may be necessary to use cylinder speeds lower than 500 rpm under the condition of excessive seed damage. Sudajan et al. (2002) applied different threshing units for sunflower seeds and reported that visible grain damage improved with increasing drum speed and feed rate. Ajav and Adejumo (2005) evaluated an okra thresher with variable parameters. The results showed that germination of threshed seeds was significantly influenced by moisture content, cylinder speed, and concave clearance. In order to determine machine-crop parameters, Vejasit and Salokhe (2004) evaluated the effectiveness of an axial flow thresher on soybean. The results indicated that moisture content, feed rate, and rotor speed significantly affected the throughput capacity, threshing efficiency, and grain damage.

A review of the literature has revealed that there is limited information on the effects of machine-crop parameter combination on the performance of cowpea threshers. The appropriate rotor speeds for optimal machine performance is considerably related to the seed moisture content (SMC). The sum of seed damage and unthreshed seed as influenced by SMC is also a necessary information in the selection of drum speeds so as to meet the acceptable seed damage level of 1.1 % (Ukatu, 2006). Majority of farmers in the rural areas do not have access to mechanical threshers and consequently, resort to manual threshing. The required seed moisture content (SMC) for effective threshing can also not be determined by majority of rural farmers and thresher operators due to lack of moisture meters. Meanwhile, it is an important parameter in determining the qualitative and quantitative loss of the threshed grains (Altuntas and Yıldız, 2007; Al-Mahasneh and Rababah 2007). Therefore, the objectives of this paper seek to: Design a portable cowpea threshing machine for use by rural farmers in Ghana; Evaluate the effectiveness on the bases of threshing efficiency, grain damage and throughput at different moisture contents; Provide the best machine-crop parameters combination for optimum machine performance in order to maintain the final product at high quality.

2. Methodology

2.1 Design procedure

The application of basic design principles including drawing and simulations were employed to design the thresher. It was developed through fabrication processes of machining, cutting and welding at the Mechanical Engineering workshop of the Koforidua Technical University. The rotor peg was loaded with a calculated maximum stress that it will undergo during operation and simulated using ANSYS Workbench 16.2. This was to determine the stress distribution in the peg to ensure that it can withstand the load based on the geometrical size (Fig. 2).

2.2 Design of the main and cleaner Shafts

The rotor and cleaner shafts are the transmission elements of the threshing and cleaning operations respectively. The rotor shaft carries the threshing drum with a bigger pulley fixed at one end to take power from the prime mover. The shafts were selected based on calculations and the properties of materials so as to withstand stress and strain from the imposed loads (Eq. 1). The shafts are made of steel material because of the load that would be imposed on them. Steel is desired because it has high strength, resistance to shock and can withstand repeated loading (Olaoye 2011). Selection of a material for a machine part or structural member is one of the most important decisions in design. Consequently, the selection was based on the strength and stiffness (Khurmi and Gupta 2005). The diameters of the shafts were obtained by the equation:

$$\tau = \frac{T}{\left(\frac{\pi d_s^3}{16}\right)} \leq \tau_{dt} \Rightarrow d_s \geq \sqrt[3]{\frac{16T}{\pi\tau_{dt}}} \quad \text{Eq. 1}$$

Where $T[Nm]$ is the torque; τ is allowable torsional shearing stress. For mild steel material the allowable torsional shearing stress is: $\tau_{dt} = 28 \text{ N/mm}^2$.

The torque is given by:

$$T = \frac{P}{\omega} = \frac{P}{2\pi n} = \frac{60P}{2\pi n} = \frac{30 \times 10^3 \cdot P}{\pi n} \text{ Nmm} \quad \text{Eq. 2}$$

Where $P (kW)$ is the power; $n (\text{rev}/\text{min})$ is rotational speed.

Based on calculations, the minimum diameters for the main and cleaner shafts should not be less than 21 and 16 mm respectively. Therefore, 25 mm and 18 mm were chosen as the diameters of the main and cleaner shafts respectively.

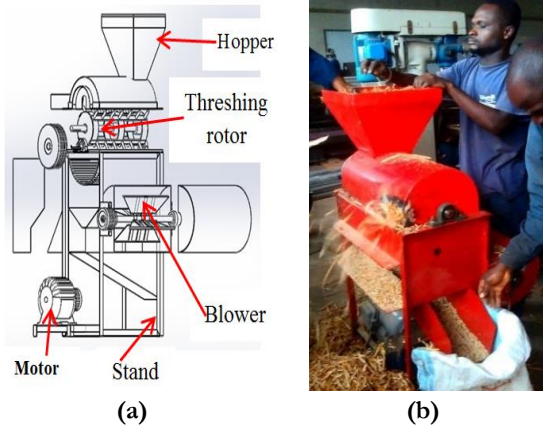


Fig. 1: (a) Isometric view of the final design and (b) Pictorial view of the developed thresher in operation.

2.3 Expressions for some of the variables used for the evaluation.

The expressions used in the evaluation process of the present study are stated below:

(i) Throughput T_{pc} in kg/h, is given by

$$T_{pc} = \frac{K_{cp}}{T_f} \quad \text{Eq. 3}$$

Where: K_{cp} is the quantity of cowpea materials fed into the thresher in kg and T_f is the feeding period in hr.

(ii) Output capacity G_{oc} in kg/h is expressed as;

$$G_{oc} = \frac{(K_f + K_b)}{T_f} \quad \text{Eq. 4}$$

where: K_f is quantity of whole grains, and K_b is the quantity of broken seeds in kg.

(iii) Seed damage K_d in %, is calculated as

$$K_d = \frac{K_b}{(K_f + K_b)} \quad \text{Eq. 5}$$

(iv) Threshing efficiency, η_t in %, is given by

$$\eta_t = \frac{G_{oc}}{(G_{oc} + K_{ut})} \times 100 \quad \text{Eq. 6}$$

where: K_{ut} the unthreshed seeds quantity in kg.

2.4 Experimental method

The seed sample was obtained from Crops Research Institute, Ghana and cultivated at the Koforidua

Technical University research farm from August 11, 2013 to November 20, 2013 at 60 x 20 planting distance. The initial average moisture content of the harvested crop is 21.26 %. The harvested cowpea was separated into five units and dried to, 20.7, 18.4, 15.3, 13.5 and 12.6% moisture contents (MC_{db}). Machine feeding was carried out continuously in three replicates for 1 hour and the average taken using 735 rpm rotor speed. The yield percentage recovery, grain damage, threshing efficiency, and unthreshed grain percent were then determined for each MC_{db} . This process was repeated for the other cowpea units. Analysis of variance was performed on the data to determine if there were any significant differences between the responses of the treatments using IBM SPSS software version 20. The sum of seed damage and unthreshed seed for the various cowpea units were computed and plotted (Fig. 3). This was done to determine the MC_{db} at which the sum of seed damage and unthreshed seeds obtained is the lowest so as to provide the best MC_{db} for optimal machine performance.

3. Results and Discussion

3.1 Stress distribution in rotor peg due to maximum possible load from calculation

The impact force simulation results obtained with ANSYS Workbench on the rotor peg is shown in figure 2. It shows that the geometrical size of the peg is enough to withstand the imposing load of the cowpea during threshing. This is because the stress distribution in the member is almost uniform along the entire length. However, the maximum stress (shown by the red colour) is highly concentrated close to the peg-rotor joint and reduces towards the tip. Furthermore, the small deflection in the peg is an indication of its resilience to a much smaller load than the cowpea can impose based on the feeding rate.

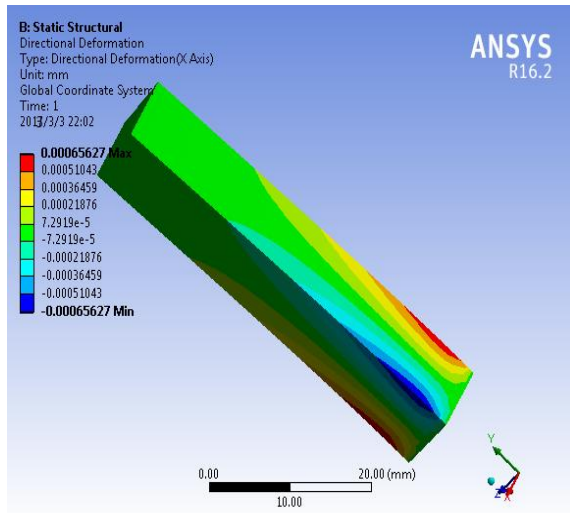


Fig. 2: Stress distribution in the rotor peg due to impact force imposed with ANSYS WorkBench.

3.2 Effects of MC_{db} on machine performance

Table 1

Performance of the thresher at various moisture contents tested

Moisture Content, (% db)	Throughput, T_{pc} (kg/hr)	Grain output, G_{oc} (kg/h)	Full grain, S_{fg} (kg)	Seed damaged, k_{sg}	Seed damaged, (%)	unthreshed seeds, k_{ug}	Threshing Efficiency%
20.7	66.28	43.8	39.66	4.14	9.46	3.02	93.11
18.4	67.80	44.5	41.03	3.47	7.81	2.47	94.44
15.3	75.22	58.7	56.10	2.06	4.43	2.07	96.47
13.5	77.02	61.7	60.64	1.06	2.67	1.08	98.25
12.6	77.56	62.6	61.57	1.03	1.64	0.38	99.40

The seed loss (sum of seed damage and unthreshed), seed damage and unthreshed obtained from the assessment have been plotted against the moisture content (Fig. 3). Threshing efficiency largely depends on the unthreshed than the damage seeds. The smaller the unthreshed seeds, the higher the efficiency. The 12.6% MC_{db} had a very small quantity of unthreshed seeds (0.38kg) resulting into the highest efficiency of 99.40%. As the seed damage trend almost plateaus, the unthreshed seeds also increases and both converged at 13.5% MC_{db} after which seed damage increased sharply and higher than the unthreshed. This point can be described as equilibrium moisture content. The seed loss trend is low at 12.6% and increased steadily to 13.5% where it increased sharply. The graph once again confirms that the best moisture regimes for optimal thresher performance should be below the equilibrium (13.5%). The other MC_{db}

The machine performance data collected from the tests under the influence of seed moisture content (MC_{db}) are presented in Table 1. The performance test resulted in the lowest throughput of 66.28 kg/h for the 20.7% MC_{db} and the highest of 77.56 kg/h for 12.6% which indicates that lower moisture contents are more effective than higher MC_{db} . The seed damage increased from 1.64 to 9.46% with increasing MC_{db} . The 12.6 and 13.5% MC_{db} proved to be better options for effective thresher performance. However, the values of seed damage percent obtained from the 12.6 and 13.5% MC_{db} were 32.9 and 36.3% respectively higher than the accepted level of 1.1 % (Ukatu, 2006). This may be due to the high rotor speed of 735 rpm used (Herbek and Bitzer, 2004) which seems to have higher influence on seed damage. Therefore, it is expected that lower speeds could bring the damage to the acceptable level. The 12.6% has proven to be the most reliable for optimum thresher performance. The full grain recovery increases with decreasing MC_{db} with the 12.6 and 13.5% achieving as high as 79.39 and 78.73% of the throughputs respectively.

performed poorly with unacceptable seed loss values. Therefore, any MC_{db} from 13.5% and above is not recommended for effective threshing.

3.3 Statistical analysis

The seed damage data in Table 1 were analysed at 5% significant level to test whether the performances of the moisture regimes are the same or otherwise.

(i) Throughput capacity: Analysis of variance performed on the data in Table 1 showed that, at 5% level of significance the throughput capacities of the moisture content provided a p-value of 0.991229 indicating that they are the same.

(ii) Seed Loss: The analysis resulted in a p-value of 0.007997 which indicates that the seed loss is not the same. However, analysing the data for the 12.6 and

13.5% MC_{db} which are the best moisture regimes resulted in a p-value of 0.177294 which indicates that there is no significant difference between them. Therefore, both MC_{db} can be relied on for optimal machine performance under lower speeds conditions.

(iii) Threshing Efficiency: This indicates that at 5% level of significance the threshing efficiencies of all the MC_{db} tested are the same in performance ($p = 0.978878$).

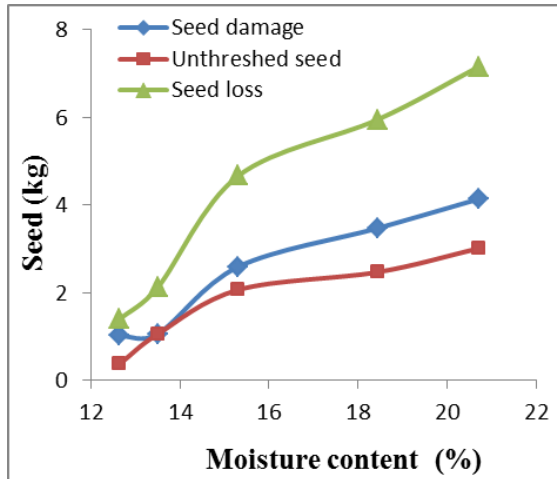


Fig. 3: Moisture content effect on seed loss (sum of seed damage and Unthreshed)

4. Conclusion and Recommendations

An Electric or Engine powered portable cowpea thresher which can be utilised by rural and small scale farmers in Ghana has been developed. The thresher was found to meet the design objectives. The moisture content (MC_{db}) was considered because of its versatility. The areas of modification were the rotor pegs and the clearances between the peg and the stationary pod splitter.

Moisture contents (MC_{db}) less than 13.5% has proven to be the best for optimum thresher performance. Analyses done at 5% level of significance indicated no significant difference in the throughput and threshing efficiencies. However, seed damage had significant difference. Subsequently, analysis performed on the seed loss data for the 12.6 and 13.5% which were the best performing moisture contents showed no significant differences. Therefore, MC_{db} less than 13.5% and rotor speeds less than 735 rpm are the crop- machine parameter combination for optimum thresher performance.

Acknowledgements

The authors are very grateful to: Maxwell Ntiamoah Bosompen and Wahab Yusif all of GRATS foundation, Koforidua, for their support in the design and construction when they were students of Koforidua Polytechnic; Godfred Birifah Oduro, Bright Martey, Elinam Justice Wovenu, Emmanuel Amponsah, Seth Kukiah and Jerry Asante who supported the project in the construction, cultivation of the cowpea, and the evaluation process.

References

- Adekanye, T. A. and Olaoye, J. O. (2013). Performance evaluation of motorized and treadle cowpea threshers. *Agric Eng Int: CIGR Journal*, Vol 15, No 4, pp 300–306.
- Ajav, E. A., and Adejumo, B. A. (2005). Performance Evaluation of an Okra Thresher. *Agric. Eng. Int.*, Vol 7, pp 1 – 8.
- Al-Mahasneh, M. A., and Rababah, T. M. (2007). Effect of moisture content on some physical properties of green wheat. *Journal of Food Engineering*, Vol 79, pp 1467–1473. doi:10.1016/j.jfoodeng.2006.04.045.
- Altuntas, E., and Yıldız, M. (2007). Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains *Journal of Food Engineering*, Vol 78, pp 174–183. doi.org/10.1016/j.jfoodeng.2005.09.013
- Fulani, A. U., Kuje, J. Y. and Mohammed, B. I. (2013). Effect of Moisture Content on Performance of a Locally Fabricated Cowpea Thresher. *Department of Agricultural Engineering. College of Agriculture, Lafia, Nigeria*, Vol 2, No 5, pp 1 – 2.
- Gomez, C. (2004). *Cowpea Post-Harvest Operations*, Food and Agricultural Organization of the United Nations (FAO) Rome, pp 2–4.
- Herbek, J. H. and Bitzer, M. J. (2004). Soybean production in Kentucky: part V- Harvesting, drying, storage, and marketing. Lexington, Ky.: Cooperative Extension Service Bulletin AGR 132.
- Irtwange, S. V. (2009). Design, Fabrication and Performance of a Motorized Cowpea Thresher for Nigerian Small-Scale Farmers. *African Journal of Agricultural Research*, Vol 4, No 12, pp 1383 – 1391.
- Kepner, R. A., Bainer, R. and Barger, E. L. (1978). *Principles of Farm Machinery*, (3rd Edition). AVI Publishing.

- Khurmi, R. S. and Gupta J. K. (2005). *Theory of Machines*, S. Chand & Co. Ltd (1st Edition) Eurasia publishing house (pvt.)Ltd. Ram Nagar, New Delhi-110 055.
- Langyintuo, A. S., Lowenberg-DeBoer, J., Faye, M., Lambert, D., Ibro, G., Moussa, B., Kergna, A., Musa, S., Kushwaha, S. and Ntougam, G. (2003). Cowpea supply and demand in West and Central Africa. *Field crops research*, Vol 82, pp 215– 231.
- Manes G. S., Dixit A., Singh A., Singh M., Singh B. P. (2015). Comparative Performance Evaluation of Axial Flow and Tangential Axial Flow Threshing System for Basmati Rice (*Oryza sativa*), *Agricultural Research*, Vol 4, No 3, pp 303–308. DOI 10.1007/s40003-015-0169-3
- Maunde, F. A. (2011). Performance Evaluation of Manual Cowpea Thresher, *African Journal of Agricultural Research*, Vol 6, No 30, pp 6412.
- Morad, M. M., El-Kot, A. S., Ali, M. M. and Salem, H. M. (2007). Study on the Mechanization of Cowpea Crop Production under Egyptian Conditions. *Misr J. Ag. Eng. Farm Machinery and Power*, Vol 24, No 3, pp 450 – 468.
- Murdock, L. L., and Baoua, I. B. (2014). On Purdue Improved Cowpea Storage (PICS) technology: 402 Background, mode of action, future prospects. *Journal of Stored Products Research*, Vol 58, pp 3 – 11.
- Olaoye, J. O. (2011). Development of a Treadle Operated Abrasive-Cylinder for Threshing Cowpea, *International Journal of Engineering Science and Technology (IJEST)*, Vol 3, No 12, pp 8548–8549.
- Sharma, K. D. and Devnani, R. S. (1980). Threshing studies on soybean and cowpea. *A.M.A.* pp 65 – 68.
- Salari, K., Amiri Chayjan, R., Khazaei, J., Amiri Parian, J. (2013). Optimization of Independent Parameters for Chickpea Threshing Using Response Surface Method (RSM). *J. Agr. Sci. Tech*, Vol 15, pp 467–477.
- Sudajan, S., Salokhea, V. M. and Triratanasirichai, K. (2002). Effect of Type of Drum, Drum Speed and Feed Rate on Sunflower Threshing. *Biosystems. Eng.*, Vol 83, No 4, pp 413–421.
- Ukatu, A. C. (2006). A Modified Threshing Unit for Soya Beans, *Biosystems Engineering*, Vol 95, No 3, pp 371–377.
- Vejasit, A., and Salokhe, V. M. (2004). Studies on Machine-Crop Parameters of an Axial Flow Thresher for Threshing Soybean. *Agric. Eng. Int. Paper No. 04 004. 12.*
- Yalcın, I. (2007). Physical properties of cowpea, (*Vigna sinensis* L.) seed. *Journal of Food Engineering*, Vol 79, pp 57–62. doi:10.1016/j.jfoodeng.2006.01.026.